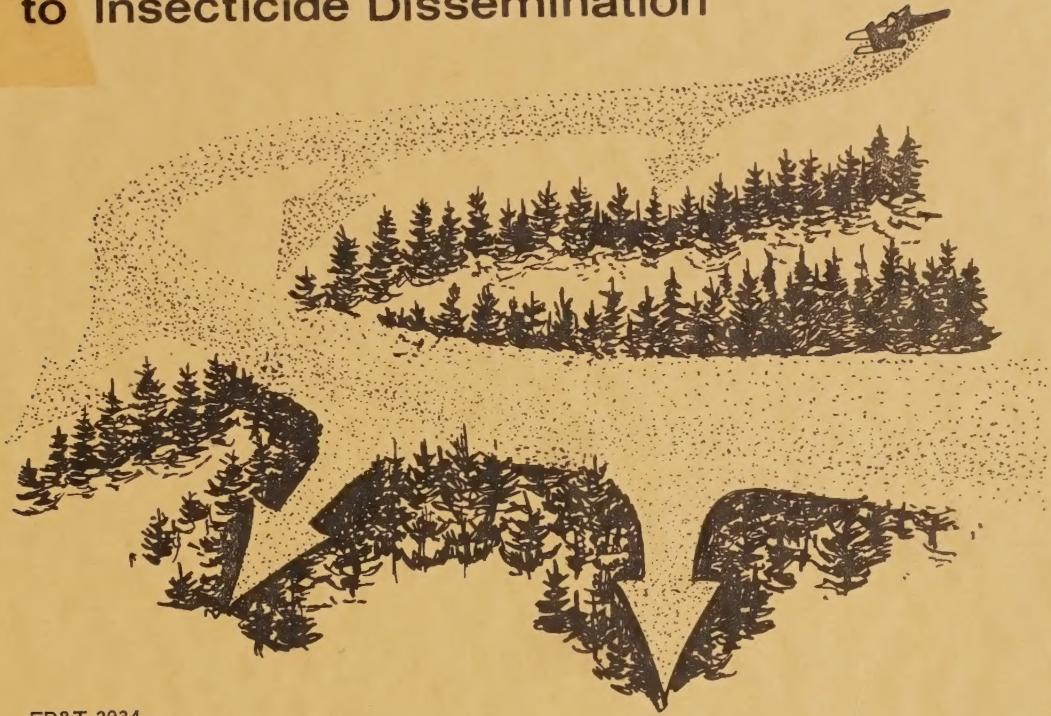
Application of "DRY LIQUIDS" to Insecticide Dissemination



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APPLICATION OF DRY LIQUIDS

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U.S. Department of Agriculture
Forest Service
Equipment Development Center
Missoula, Montana

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APPLICATION OF "DRY-LIQUIDS" TO INSECTICIDE DISSEMINATION

by

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for

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Disclaimer

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Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and/or federal agency before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides in pesticide containers.

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I. INTRODUCTION

The western spruce budworm is one of the most destructive forest insects in North America. Emerging in the spring, they attack the opening buds on conifers and feed on the tender needle tips. When attacks are heavy, entire trees are stripped of foliage. Moderate attacks reduce growth, weaken trees, and leave them susceptible to later destruction by other insects and disease. From 1946 to 1964 the western spruce budworm infestation was suppressed by aerial application of DDT. However, as is well known, the use of DDT was terminated because of adverse effects on other animal life and its chemical persistence. Therefore, work was started about 1964 by the Forest Service Pacific Southwest Experiment Station in Berkeley, California to find a nonpersistent chemical with a relative degree of selectiveness for the spruce budworm. Five years of research produced a registered formula of Zectran[1/] (FS-15) for spruce budworm control.

Laboratory work during that research period disclosed that the highest rate of mortality of the insect was achieved by contact with droplets less than 50 microns in diameter. Concurrent with the later stages of this research work the Equipment Development Center at Missoula, Montana was developing methods of producing the desired droplet spectrum. A good system for disseminating the

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1/ Zectran is a trademark used by Dow Chemical Company.

material in liquid form was developed, and has been used successfully in C-47 aircraft. However, achieving the small droplets from a liquid presents technical problems. The equipment is heavy and bulky, which means that payload is sacrificed. Therefore, further investigation was initiated to determine if other means were available to disseminate the insecticide in the desired droplet size without the penalties imposed by conventional methods. This led to the concept of "dry liquids."

This paper is a progress report on the work done by the Equipment Development Center at Missoula, in cooperation with other agencies, to determine the feasibility of utilizing dry liquids for the application of Zectran.

II. DESCRIPTION OF MATERIAL

German scientists were apparently the first to investigate the dry-liquid concept, originally called carrier-dust, as a means for employing chemical agents which could not be dispensed by the usual methods. Their work was primarily concerned with the use of alumina gel and fuller's earth as the carrier dusts. They carried their work far enough to establish that these carriers could be effectively coated with a liquid yet retain their dust characteristics. Hence the term "dry-liquid."

In 1948, the work begun by the Germans was picked up and further investigated by the U. S. Army Chemical Corps at Edgewood Arsenal

in Maryland. The physical characterizations of the carriers were defined, and the feasibility of the technique for disseminating chemical agents was demonstrated. The Center learned of this work during the investigation and it provided the background needed to conduct further work.

Dry liquid mixtures consisting of the desired particle sizes offer distinct advantages over liquid mixtures, such as: (1) ease of handling and storing, (2) ease of dissemination, (3) simplicity in laboratory assessment, and (4) minimum evaporation. It was also mentioned earlier about bulk and weight of equipment for dissemination of the liquids in the small droplets required, so it was all of these factors which provided the impetus to continue development of this concept.

During the tests described later in the paper two carrier materials were used. They were Micro-Cel E and Hi Sil 233, which are hygroscopic silicates.

The carriers were coated with the Zectran (FS-15) insecticide at a ratio of 60 percent FS-15 to 40 percent carrier in one test and 50 percent FS-15 to 50 percent carrier in another.

As tracers, Tinopal, a water-soluble blue fluorescent material, and Chartreuse pigment 720, a fluorescent material soluble in acetone, were used.

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These materials were blended in a Patterson Kelly liquid-solid blender shown in Figure 1.

III. PRELIMINARY TESTS

Initial work took place in the laboratory, primarily in investigation of different types of carriers and varying ratios of liquid to carrier. Combinations as high as 70 percent liquid to 30 percent carrier were tried before arriving at an optimum of 50-60 percent liquid to 50-40 percent carrier. Generally, retention of the dust characteristics was studied during this phase of the work. This also demonstrated that the hygroscopic silicates had the greatest potential as carriers.

The first aerial tests were made using an inert material solely for the purpose of testing its application with conventional dusting equipment and utilizing drainage winds for transporting the dust into the foliage of the trees.

The test was conducted close to Missoula. Several loads of the material were dropped using a Cessna Agwagon 300 aircraft equipped with a Transland Swathmaster spreader, standard agricultural equipment. This is illustrated in Figure 2. Figure 3 shows the dry-liquid spreading down the drainage.

IV. FIELD TRIALS

After the preliminary tests it was evident that there was a need for much more data and spray deposit evaluations. Prediction of cloud

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Figure 1.--Patterson Kelly liquid-solid blender.

Figure 2.--Cessna 300 Agwagon with Swathmaster crop duster.

Figure 3.--Agwagon disseminating inert dry-liquid.

travel, sampling techniques, and laboratory assessment were areas that would need greater emphasis. It was found at this time that Deseret Test Center (DTC) had years of experience, facilities, and technical expertise in spray deposit assessment and meteorological modeling. In the two tests that followed, therefore, DTC was able, through cooperative agreements, to provide meteorological and aerosol sampling equipment, personnel, and laboratory analysis of sampler data. Also, Metronics, Inc., under contract, furnished particle characterization data.

The first field test took place in June 1971 on the Nezperce National Forest in Idaho. The selected site met the criteria of vehicular access to an established base camp, moderate infestation of the spruce budworm, and topography for drainage winds during late evening and early morning hours. The area was located in a steep draw, trending downward west to east between two ridges about 4800 feet above sea level. The site was forested with a mixed stand of Douglas-fir, grand fir, and ponderosa pine with an estimated maximum height of 90 feet. The ground cover and understory were relatively open as a result of grazing of cattle.

Because of the limitations involved in aircraft operations in mountainous terrain, time of day for dissemination is critical. Depending on the season and terrain orientation, drainage winds normally exist from 2000 hours until shortly after sunrise. For safe operation of aircraft, good visibility is necessary. By

observing meteorological conditions for several days, the ideal time for dissemination for this test was determined to be around 0430 hours. This time was validated by smoke releases and by meteorological sampling within the site.

The stage of development of the budworm is also critical to achieve the highest probability of kill. Most ideal stage is to 50 percent or more in the 5th or 6th instar. This timing was verified by entomologists sampling the insect population periodically, and finally each day until the proper time is reached.

When it was apparent that the budworms were at the proper stage all instrumentation and sampling devices were installed at pre-determined locations within the test site. The equipment and techniques are described in Section V.

The Zectran insecticide mixture was disseminated upwind of the test site with the Cessna Agwagon equipped with a Swathmaster duster.

With all in readiness the actual test took place on June 30, 1971 at 0500 hours. Aircraft speed was 120 mph. From a height of about 50 feet above the treetops, 435 pounds of material were dropped. Pictures of the drop are shown in Figures 4 and 5.

After the tests, samples of the material were analyzed by Metronics, Inc. to determine particle size spectrum.

Figure 4.--Dissemination of Zectran dry-liquid mix.

Figure 5.--Dry-liquid particle cloud spreading in drainage.

The second field test took place in June 1972 on the Lolo National Forest near Missoula, Montana. The site selected was divided into two plots, each about 200 feet by 300 feet in size. Both were located on a broad, flat ridge at about 3800 feet elevation. Douglas-fir was the predominant species with ponderosa pine mixed in and a very few western larch. Ninebark was the primary understory species. Plot 1 had about 217 trees per acre, and plot 2 was much less dense at about 97 trees per acre. There were a few openings in the plots ranging from 50 to 100 feet in diameter, with one large opening in plot 2 about 200 feet in diameter.

For this test a Bell G-3 helicopter equipped with a standard Simplex duster was used for disseminating the dry liquid mixture. The aircraft speed was about 30 miles per hour with the release height about 50 feet above the canopy. The release line was marked by tethered balloons. The helicopter made three passes over the test plots, releasing a total of about 21.6 pounds of insecticide mixture, or 5.4 pounds per acre.

Prior to the test, samples of the insecticide mixture (carrier, insecticide, tracer) were evaluated by DTC to determine the stability of the tracer when exposed to sunlight.

A sample of the mixture was characterized by Metronics, Inc. to determine number of particles per gram and particle size distribution.

The helicopter equipped with duster is illustrated in Figure 6. Figure 7 shows the helicopter in flight.

V. SAMPLING EQUIPMENT AND TECHNIQUES

Meteorological sampling.--Consisted of low threshold type wind direction and speed sensors (Climet CI-3) mounted on towers within the test areas as illustrated in Figure 8. All wind sensor signals were telemetered to translators and recorded on analog Esterline Angus recorders. In addition, pilot balloon observations were made to determine the upper air flow above the canopy. Standard surface observations were taken to obtain temperature, relative humidity, sky cover and weather phenomenon.

Particle sampling.--On the first test two types of aerosol samplers were employed, the Rotorod sampler and a membrane filter sampler. This duplicate instrumentation was used to determine their relative efficiencies and ease of handling under field conditions. The Rotorod is a small U-shaped rod coated with silicone grease and rotated by dry cell battery (Fig. 9). These were mounted on wooden sticks within the test areas. They were equipped with a mechanical timer to activate them at a preset time prior to the test, and deactivate them 1 hour later.

The membrane filter was a portable Gelman sampling unit. These were located at the same positions as the Rotorods (Fig. 10). The purpose of these instruments was to obtain aerosol dosage measurements

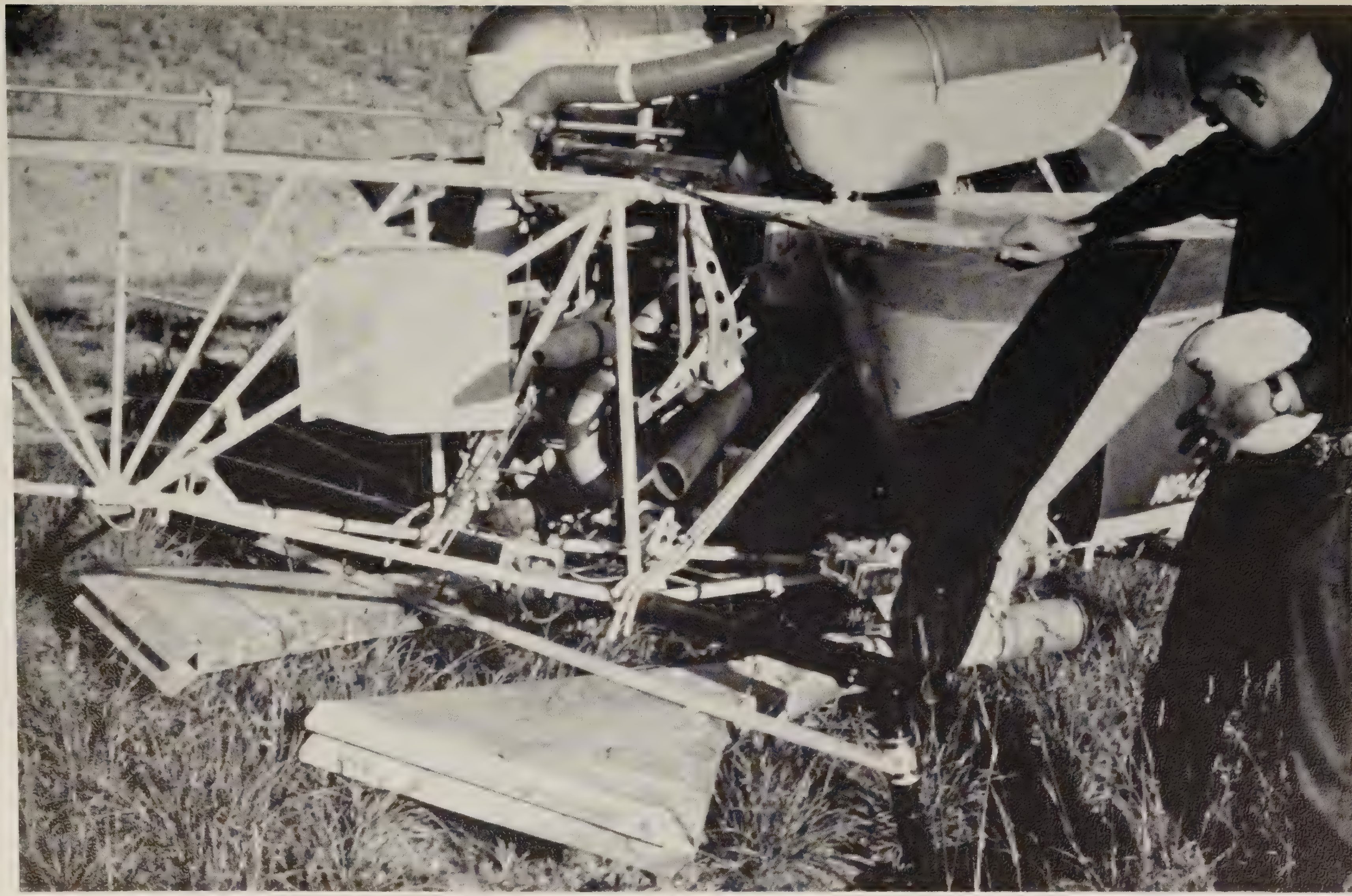

Figure 6.--Bell G-3 helicopter equipped with Simplex duster.

Figure 7.--Helicopter disseminating dry-liquid mixture.

Figure 8.--Tower equipped with meteorological instruments.

Figure 9.--Silicone grease-coated rotorod and glass impaction plate.

Figure 10.--Gelman sampling unit adjacent to rotorod.

throughout the test grid and to define the lateral coverage of the aerosol.

On the second test the Rotorod only was used because of its ease of handling and low cost. Glass impaction plates covered with silicone grease were added to determine quantatively where the aerosol impacted on the grid and the size range of the impacting particles (Fig. 9).

The insecticide particles on the Rotorod and membrane filter samples were counted by DTC. The fluorescent material, which was added to the insecticide mix, was excited by ultraviolet light. Particle counting was performed by means of an ultraviolet light source adapted to the counter's microscope. Each particle on the membrane filter and Rotorod exhibited a degree of fluorescence which permitted individual particle counting.

Metronics, Inc. determined the particles per gram and particle-size distribution of a sample obtained from the disseminator.

<u>Biological sampling</u>.--Sample trees were selected and marked within the plots. Prespray insect surveys were conducted in the test areas approximately 24 hours prior to spray release for the purpose of establishing the prespray level of the spruce budworm population. Four branches were removed with modified pole pruners at mid-crown level from each of 10 sample trees within each grid (Fig. 11). The branches were placed in polyvinyl bags and labeled to identify the locations of the trees within the grid from which they were pruned.

Figure 11.--Removing branch sample with pole pruner.

The bags were retained in a cold storage room until such time as the branch samples could be examined in the laboratory. In the laboratory, all buds on the branch were dissected to expose the budworm larvae. The number of larvae per 100 buds was recorded as an indication of the intensity of budworm infestation for that tree from which the branches had been pruned. The same procedures were followed to establish the level of spruce budworm population following completion of the spray mission. Postspray samples were taken 4 days after completion of spraying.

In addition to collecting prespray samples of Douglas-fir, branch samples also were obtained (in the manner described) for the purpose of studying particle impaction on foliage. The branches were collected the morning following the spray test. The terminal 4 inches of new foliage growth was selected at random from each branch sample and examined under a dissecting microscope equipped with ultraviolet light for the presence of fluorescent dry-liquid Zectran particles. The fluorescent particles were counted, measured with an ocular micrometer and their location on the foliage recorded.

Four trees in each plot were selected as sample trees to investigate particle impaction on the budworm larvae. A plastic drop cloth was placed beneath each tree to collect the falling larvae. On the morning following the test approximately 100 budworm larvae were collected at random from each drop cloth and placed in 135 mm metal film cans for transportation to the laboratory.

A postspray sample was taken, following the prespray sampling procedures, for comparison with the prespray count to establish percent mortality. This was done on each of the two test plots.

VI. DISCUSSION

A detailed listing of results and conclusions does not seem appropriate at this point in the development of the system of insecticide dissemination. Insect mortality has been less than significant, 0 percent in one test and 33 percent in the other, but so far this factor has only been monitored as an indicator and was not set up as a prime objective. We have learned that dissemination from both fixed wing aircraft and from helicopters is practical and feasible. Certainly the instrumentation and analytical methods supplied by DTC are essential to the evaluation of the material and technique.

The most pertinent information gathered to date is that regarding particle size of the material and its relationship to impaction on the target. The amount of insecticide which came in contact with the budworm and was retained is very important. There is evidence that very little deposition and impaction of small particles actually takes place. Since the number median diameter of the dry liquid mix in these tests were approximately 2 microns, the chance of a sufficient dose hitting any budworm was very remote. The impaction efficiency of particles in this size range has been calculated to be less than 1 percent.

Particles less than 5 microns in diameter are suspended in the air as a gaseous material and probably have a very small chance of impinging on the plant needles. Particles smaller than 1 micron usually do not even reach the treated stand. Because of the low settling velocities involved, the main mechanisms which delivered the Zectran-coated particles to the target insect were transport and diffusion rather than settling. However, deposition is impeded by air turbulence microcurrents around the plants and by the wind which blows the particles from the treated areas.

Probably the best indicator of problems encountered in these tests is illustrated on the graphs, Figures 12 and 13. Figure 12 shows the particle distribution by "mass" and Figure 13 by "number." It is very obvious that the largest percentage of particles were in an ineffective size range.

This also indicates one hazard in the specification of particle size. Commonly engineers and entomologists have specified size by "mass median diameter." Unless all of the ramifications of the definition of "mass median diameter" are clearly understood it is easy to be misled into believing that the particle distribution is what is desired. However, the graph of mass distribution shows just a very few large particles can give a false indication of the overall distribution. It would undoubtedly be best to have the distribution analyzed by both mass and number. Unless the particles can be sized more precisely within a given range, it may be necessary

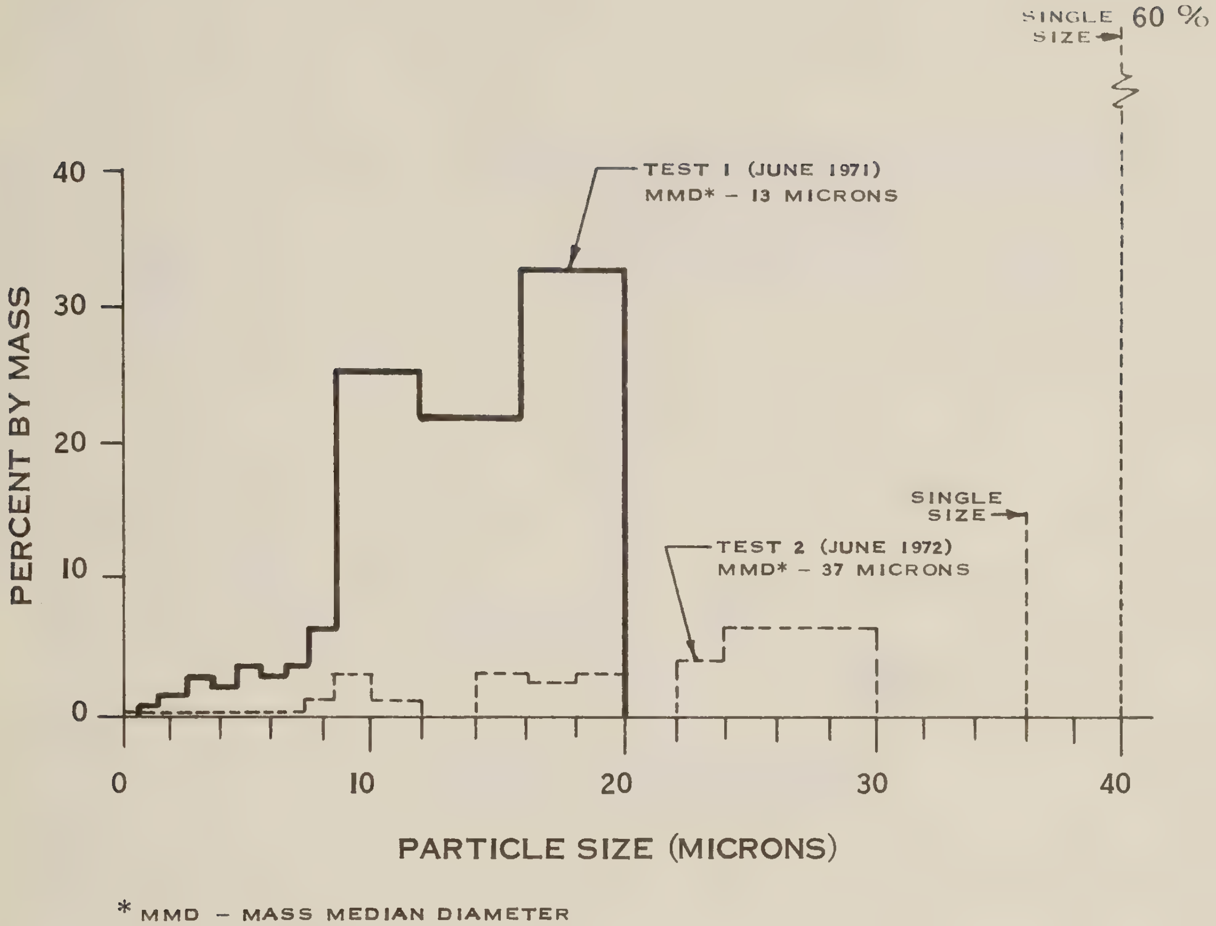

Figure 12.--Particle size distribution by mass.

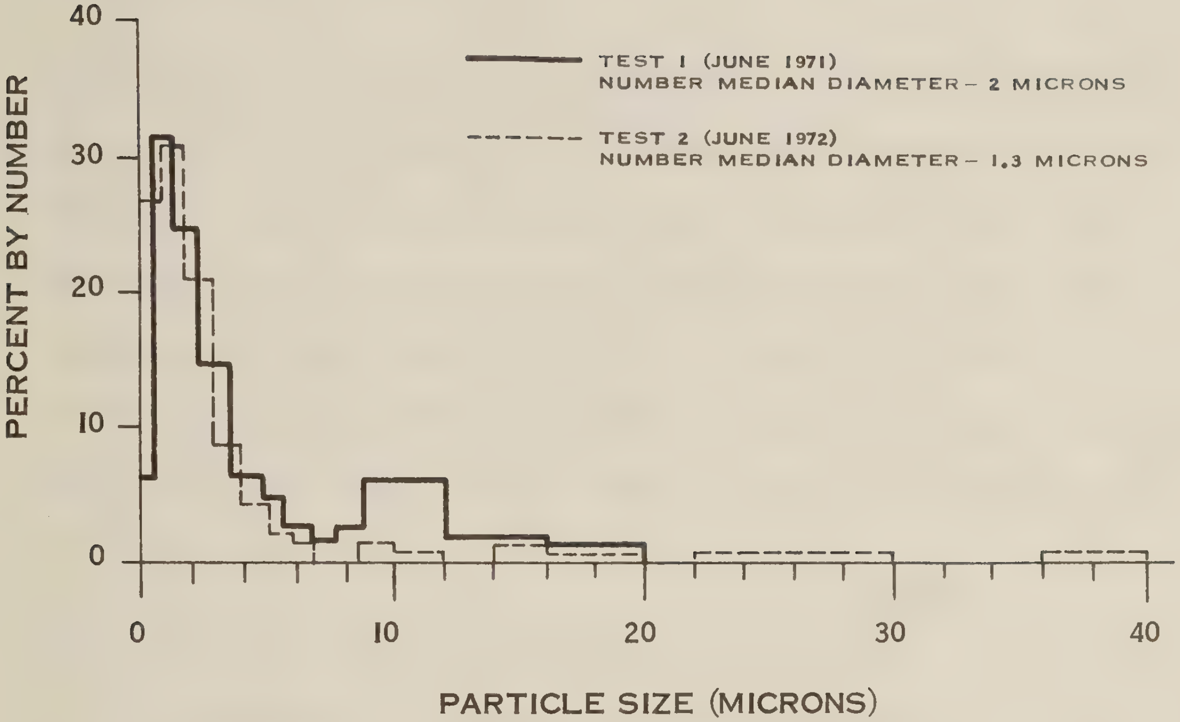

Figure 13.--Particle size distribution by number.

to specify, for instance, a mass median diameter in the 80 to 100 micron range to achieve the most effective spectrum in the 30 to 50 micron range.

Based on the results of field tests and the factors discussed above, more information and knowledge of droplet size definition and behavior is required, particularly in the 20 to 80 micron range. Therefore, work is being done this year through wind tunnel tests by Dugway Proving Grounds. There will be much less emphasis on field testing, with efforts directed more toward laboratory evaluation and simulation. Dugway has this expertise and facilities and will be cooperating with us in the studies.

Also, in relation to the impaction problems, there will be more work on the relationship of particle size to insect mortality. Forest Service Research activities will be cooperating in this effort.

Probably further efforts in meteorological modeling will be required to more fully understand the dynamics of particle travel in and around forest canopies. Much has already been done in particle cloud travel in open areas by Dugway, but heavily forested areas present an entirely different situation.

In conclusion, this system of dissemination of insecticides offers great promise in overcoming past problems and hazards in spraying toxic materials. It simplifies handling and equipment, and provides an opportunity for more closely controlled distribution. Although

only Zectran has been used so far, it certainly will have application in any agricultural work.

The comments presented in this paper are an oversimplification of the work and studies that have been conducted to date. Much greater detail on all aspects of the project are covered in the documents listed in the bibliography.

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